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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No.

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Helge	SEETZEN	Montreal, CANADA

Additional inventors are being named on the ______ *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Method for Efficient Computation of Image Frames for Dual-Modulation Display Systems Using Key Frames

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

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OR

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages* 3

☐ Drawing(s) *Number of Sheets*

☐ Application Date Sheet. See 37 CFR 1.76

☐ CD(s), Number

☐ Other (specify)

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☑ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees.

☐ The Director is herby authorized to charge filing fees or credit any overpayment to Deposit Account Number:

☑ Payment by credit card. Form PTO-2038 is attached.

FILING FEE Amount ($): 80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☑ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

SIGNATURE [signature]

TYPED or PRINTED NAME ANNARI FAURIE

TELEPHONE 604-822-8594

Date 30 April 2004

REGISTRATION NO.
(if appropriate)
Docket Number: UBC 04-124

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

THE UNIVERSITY OF BRITISH COLUMBIA

April 30, 2004

Hon. Commissioner for Patents
2011 South Clark Place
Crystal Plaza Two, Lobby, Rm 1B03
Arlington, Virginia 22202

Dear Sir:

Re: Provisional Patent Application for "Method for Efficient Computation of Image Frames for Dual-Modulation Display Systems Using Key Frames"
UBC file no: 04-124

Enclosed please find the necessary documents for filing a Provisional Patent Application for the above-identified technology on behalf of The University of British Columbia. Also enclosed is Credit Card payment form PTO-2038 to cover the cost of the $80.00 application fee.

Thank you,

Sincerely,

Annari Faurie
Patent Manager

Encl.

U·I·L·O

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TO: **Mail Stop Provisional Patent Application**
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Arlington, Virginia 22202

Enclosures:

1. Provisional application for patent cover sheet
2. Specifications, 3 pages
3. Credit card payment form PTO-2038 for $80.00 filing fee

Method for Efficient Computation of Image Frames for Dual-Modulation Display Systems Using Key Frames

Real time Video Computation for High Dynamic Range Displays

A dual modulation high dynamic range (HDR) display (see US patent application serial number 10/469,473, incorporated herein by reference) uses two image modulators in series. Three key implementations have been designed so far: A controlled array of light emitting diodes (LED) or other light sources projecting light through a liquid crystal display (LCD), a bright backlight projecting light through two LCDs in series, and a video projector projecting light through an LCD. In order to avoid alignment artifacts between the two modulators each design uses a varying degree of resolution mismatch between the two modulators where the front LCD is high resolution colour and the rear modulators (LED, first LCD, projector respectively) is low resolution. The front image is modified to correct for the blur of the rear image such that the combined output image is a high resolution HDR image. In the following we describe the first (LED based) design for the discussion but the method applies to all HDR display designs with a resolution mismatch between the modulators.

One of the drawbacks of this system is that the rendering (computation on the graphic card) of the image couplet is very computationally expensive. In principle, images are rendering in the following way:

1. A floating point or higher than 8-bit image ("input image") is provided to the algorithm
2. Appropriate intensities for each LED are established. The corresponding driving levels are stored ("LED Values").
3. The effective luminance distribution from the entire LED array is calculated by adding the modulated point spread functions (PSF) of the LEDs together. This is very costly as each image pixel has to be rendered multiple times to account for light coming from all LEDs with a PSF that stretches onto that pixel.
4. The input image is divided by the effective luminance distribution to yield the LCD image.
5. Both LCD image and LED values are sent to the display
6. At the display the LED array is modulated by the incoming LED values to create the effective luminance distribution which is then optically modulated by the transmission of the LCD according to the LCD image. The final image output corresponds to the input image.
7. This process is repeated for the next image frame.

This invention describes a method to reduce the computation time associated with the third step, which is the most costly. Instead of following the above procedure for each frame of the image we can assume that from one frame to the next there are only small changes to the image. As a result it is possible to calculate a single LED image (LED values and the associated effective luminance distribution) and then use it for one or more additional frames. The LCD image will be continually modified to make the necessary changes from frame to frame but this is computationally much less costly. By using an LED key frame every third frame the computation cost would be approximately 1/3 of the cost associated with frame by frame computation and the procedure would look like this:

1. calculate LED key frame
2. divide first frame by LED key frame to get first LCD image
3. display LED key frame and first LCD image
4. divide second frame by LCD key frame to get second LCD image
5. display LED key frame and second LCD image
6. divide third frame by LCD key frame to get third LCD image

7. display LED key frame and third LCD image
8. calculate second LED key frame
9. divide fourth frame by second LED key frame to get fourth LCD image
10. display second LED key frame and fourth LCD image
11. etc

As will be obvious to one skilled in the art, very simple modifications to this procedure will enable the use of LED key frame changes every second, fourth, fifth ... nth, frame.

The frames between key frames will be very accurate as long as the luminance changes during a key frame sequence are minor and can be contained within the dynamic range of the LCD alone (200:1 for a standard LCD which is significantly higher that most frame-to-frame luminance changes). The only artifacts introduced by this method occur if in a particular key frame the LCD dynamic range is already used to the maximum to correct for a high contrast boundary in the image and that boundary becomes even higher contrast in a subsequent non-key frame. These situations are very rare and are unlikely to be visible at video rates.

These artifacts can be further reduced by a dynamic use of the key frames. Instead of fixing their occurrence to once ever few frames it is possible to establish one key frame and then keep count of the number of pixel per new frame which are not accurately reproducibly just by modifying the LCD image. If a certain threshold is exceeded the software renders a new key frame and otherwise no changes are necessary. Since the process of dividing the new frame by the LED key frame is very fast (linear process of one division operation per pixel) this could happen without any major delay. If the number of artifact pixels is higher than the threshold then the software calculates and uses a new LED key frame. If not, then the calculations for this frame are done (the division has already yielded the LCD image in addition to the number of artifact pixel). Such a dynamic key frame structure could dramatically reduce computation time for some applications where for long periods no major luminance changes occur in a scene.

If a key frame needs to be computed then the resulting lag can be distributed over several frames. In the interim period between the failure of the old key frame and the finished calculation of the new key frame it is possible to use different approximation of the accurate key frame. Any choice of combination from the list of options is appropriate:

- The interim frames can use a standard key frame. A standard key frame would be an approximately appropriate pattern that has been pre-computed. The system can rapidly execute a search through a list of pre-computed pattern to determine which is most suitable for the interim period. Examples of common pre-computed key frames are
  - all LEDs on at mid level
  - all LEDs full on
  - half or quarter of the LEDs full on
  - half or quarter of the LEDs half on
  - all previously computed key frames

- It is also possible to compute an interim key frame rapidly by relaxing the accuracy requirements of the LED point spread simulation (i.e. simulating the actual light distribution per LED with an approximate Gaussian, etc). This method will reduce the lag between key frame computations and the introduced imperfections are unlikely to be visible to the viewer as the result will be approximately accurate and perfect accuracy will be reached very rapidly once the new key frame is available. The accuracy of this approximation can be increased at each frame until the next perfect key frame has been established

- Since the pixels that cannot be reproduced with the old key frame are known it is possible to replace just the LED values corresponding to those pixels. Since the LED values of the old key frame are known it is possible to locate the inappropriate LED, subtract its point spread function multiplied by the corresponding LED value in the old key frame from the old key

frame. This effectively provides the LED luminance pattern under the old key frame setting with the inappropriate LED missing. The next step is to establish the appropriate LED value by the usual method. This new value multiplied by the point spread function of the LED can then be added to the modified key frame. This process is repeated as often as necessary until all inappropriate LED values have been replaced. The key frame is now appropriate for the image again. This update can take several frames and should proceed in the order of greatest error (i.e. the first LED to be replaced is the one with the largest number of pixels that cannot achieve the required value with the old key frame.)